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OPTIMIZATION OF GRIPPER CONFIGURATION BY GENETIC ALGORITHM

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ABSTRACT

An algorithm to find out the optimum configuration from a list of possible options are carried out in this paper. An equation relating input force applied and output obtaining are found out for each configuration by the help of static force analysis. Friction and dynamics characterize are not considered since they do not affect on grasping force or effect equally on different configurations. Genetic algorithm which is a tool in MATLAB is used to find the best possible values for each link. By comparing the function value and choosing the extreme value, optimum configuration can be found out. On that basics, best configuration and its link length values are found.

***KEYWORDS:** Robotics, End Effectors, Gripper, Optimization, Genetic Algorithm & MATLAB*

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Original Article

INTRODUCTION

Robots are the future assistance of mankind. Nowadays robots are becoming self-controlled because of the advancement of Artificial intelligence. Robots are now able to do every job a man can do, and more than what a man could do. They can work under extreme temperature conditions or acidic atmosphere where human does find it difficult to work. Since they can be remotely controlled it make it easy for human to control robots from a safer secured place. Robotic Industries Association defines a robot as follows "*A robot is a reprogrammable, multifunctional manipulator designed to move material, parts performance of a variety of tasks*". Depending on the tasks to be executed by the robot, design also varies. Even though 95% of robot's components are same, remaining 5% really does a lot. End effectors are part of the remaining 5%. They are the hands of a robot. Depending of the function of robot, end effectors can vary.

The grippers are one of such end effector which are designed to do pick and place applications. So many types of grippers are available, depending on criteria like actuating force, type of motor used, number of links, type of configuration adopted, grippers can be classified accordingly. In this paper 3 gripper configurations are considered and from those optimal configuration is calculated.

Theory

There are several forces which are to be carried out during the optimization process. Forces, which are crucial in designing of a gripper configuration area,

- Static force analysis.
- Kinetic force analysis.

- Force to displace.
- Force of inertia through rotation.

Among the varies forces we are concentrating only on static force analysis. Since it is the only variant which affect the gripping force while try to grip. So, we will discuss how it's possible to do the static force analysis to a gripper configuration.

Consider a basic configuration as shown in figure 1.

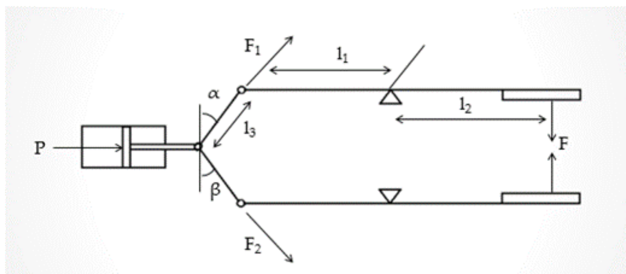


Figure 1: Basic Gripper Mechanism

To find relation between input force P and output force F, first we need to split the input force P to two F_1 and F_2 on each branch.

$$P=F_1\sin(\alpha)+F_2\sin(\beta) \quad (1)$$

For convince let's assume symmetry, that is angle made by F_1 and F_2 are same and F_1 and F_2 is equal in magnitude, then we get,

$$P=2F_1\sin(\alpha) \quad (2)$$

Now consider moment about pivot point. We get,

$$F_1\cos(\alpha)l_1=Fl_2 \quad (3)$$

On combining equations, we get

$$P=F\frac{2l_1\sin(\alpha)}{l_2\cos(\alpha)} \quad (4)$$

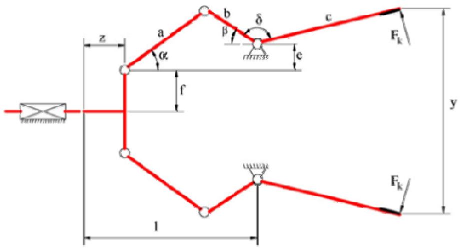
The same method can be adopted for almost all configurations.

OPTIMIZATION LINK DIMENSION

Consider 4 arbitrary configurations for optimization purpose, each configuration has its own optimum dimensions and intermediate angles.

Configuration I

Considering a configuration as shown in figure 2. Link lengths are represented by variables a, b, c & f and intermediate length are represented by e, l & z. angle α represents horizontal angle between link a and horizontal. angle β represents horizontal angle between link b and horizontal. Angle δ is used to represented by angle between links b & c.Like the method explained earlier,



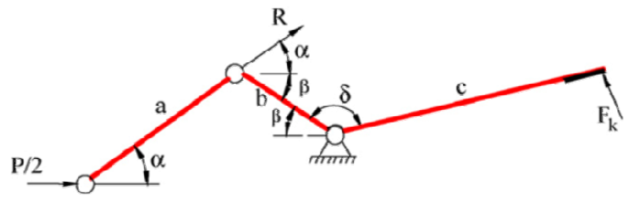


Figure 2: Configuration 1 **Figure 3: Configuration 1 Free Body Diagram**

$$P = 2F_1 cos(\alpha) \tag{5}$$

Considering free body diagram,

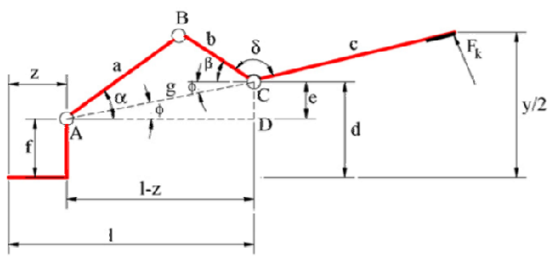
$$P = 2Rcos(\alpha) \tag{6}$$

Now let’s consider the momentum about pivot.

$$\mathrm{R}\sin(\alpha + \beta)\,\mathrm{b} = \mathrm{F}_k \mathrm{c}\sin(\beta + \delta) \tag{7}$$

On combining equations, we get,

$$\mathrm{F}_k = \frac{\mathrm{Pbsin}(\alpha+\beta)}{2\mathrm{c}\cos(\alpha)\sin(\beta+\delta)} \tag{8}$$



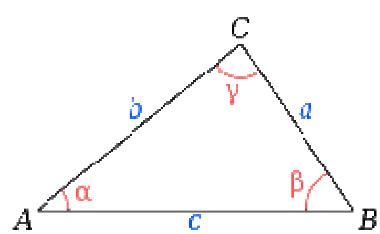


Figure 4: Configuration 1 Link Relation Diagram **Figure 5: Triangle with Sides a, b and c**

From Δ ADC,

$$g^2 = (l - z)^2 + e^2 \tag{9}$$

Law of cosines relates lengths of sides of a triangle to the cosine of one its angle.

Using notation as in Figure5, the law of cosines states

$$b^2 = a^2 + c^2 - 2ac\cos(\beta) \tag{10}$$

From Δ ABC,

$$b^2 = a^2 + g^2 - 2ag\cos(\alpha - \Phi) \tag{11}$$

which implies,

$$\alpha = \cos^{-1}\left(\frac{a^2 + g^2 - b^2}{2ag}\right) + \Phi \tag{12}$$

From Δ ABC

$$a^2 = b^2 + g^2 - 2bg\cos(\beta+\Phi) \quad (13)$$

which implies,

$$\beta = \cos^{-1}\left(\frac{b^2 + g^2 - a^2}{2bg}\right) - \Phi \quad (14)$$

From Δ ADC

$$\Phi = \tan^{-1}\left(\frac{e}{l-z}\right) \quad (15)$$

Parameters which act as variables are link length a, b, c and intermediate lengths e, l, z and angle δ. Analysing each configuration we could find that,

$$(a+b)^2 - l^2 - e^2 > 0 \quad (16)$$

$$(l - z) > 0 \quad (17)$$

Depending on the configuration each variable will be having their own limits.

For configuration 1,

$10 < a < 150$ $100 < c < 200$ $100 < l < 300$ $1.57^r < \delta < 4.09^r$ (90^o - 235^o)

$10 < b < 150$ $0 < e < 50$ $50 < z < 100$

Genetic Algorithm is the function which I have used to get the optimum result. It's a method used in MATLAB to solve constrained and non-constrained problems based on repeatedly modifying population of individual population. MATLAB programing was done in 3 different stages.

- Program to define the optimization equations.
- Program to define constrain functions.
- Program calling for optimization equation function and constrain function to do the genetic algorithm.

To obtain optimized result for each configuration, corresponding equation has been altered and proper limits are applied. MATLAB output is tabulated in table 1

Table 1: Optimum Values for Configuration 1

Variable	a	b	c	e	l	z	δ	fval
Opt - Values	40.40	129.60	196.08	30.91	177.26	99.98	3.50	0.022

Configuration II

Considering a configuration as shown in figure 6. Link lengths are represented by variables a, b, c & f and intermediate length are represented by e, l & z. angle α represents horizontal angle between link a and horizontal. angle β represents horizontal angle between link b and horizontal.Considering free body diagram Figure 7,

$$P = 2R\cos(\alpha) \tag{18}$$

Now let's consider the momentum about point c and combining

equation, $F_k \sin\beta = bF(\sin\alpha\cos\beta + \cos\alpha\sin\beta)$ (19)

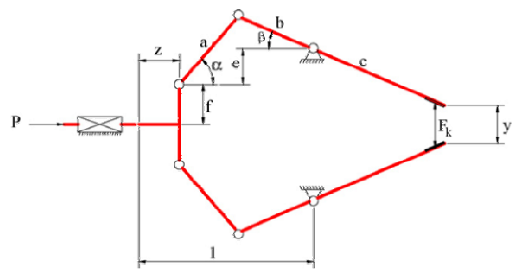


Figure 6: Configuration 2

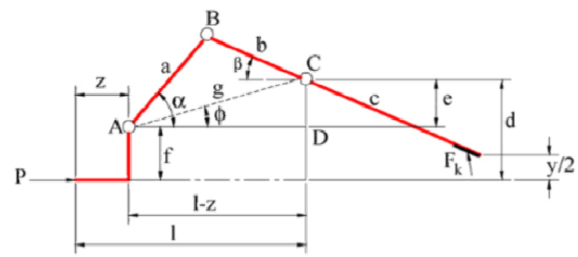


Figure 7: Configuration 2 Free Body Diagram

$$F_k = \frac{Pb\sin(\alpha+\beta)}{2c\cos(\alpha)\sin(\beta)} \tag{20}$$

From Figure 7 we can define link relations as,

From Δ ADC,

$$g^2 = (l - z)^2 + e^2 \tag{21}$$

By law of cosines & From Δ ABC,

$$b^2 = a^2 + g^2 - 2ag\cos(\alpha-\Phi) \tag{22}$$

which implies,

$$\alpha = \cos^{-1}\left(\frac{a^2 + g^2 - b^2}{2ag}\right) + \Phi \tag{23}$$

From Δ ABC

$$a^2 = b^2 + g^2 - 2bg\cos(\beta+\Phi) \tag{24}$$

which implies,

$$\beta = \cos^{-1}\left(\frac{b^2 + g^2 - a^2}{2bg}\right) - \Phi \tag{25}$$

From Δ ADC

$$\Phi = \tan^{-1}\left(\frac{e}{l-z}\right) \tag{26}$$

For configuration 2 we have constant δ of 180^o or 3.14^r and all remaining range same as that of configuration 1. MATLAB output is tabulated in table 2

Table 2: Optimum Values for Configuration 2

Variable	a	b	c	e	l	z	δ	fval
Opt - Values	22.25	72.75	132.23	0.72	146.10	51.10	3.14	0.0039

Configuration III

Considering another configuration as shown in figure 8. Link lengths are represented by variables a, b & c. Variables b and c together constitute a single link. Intermediate length is represented by e, l & z. angle α represents horizontal angle between link a and horizontal. angle β represents horizontal angle between link b and horizontal. Considering free body diagram Figure10,

We get,

$$P = 2Rcos(\alpha) \quad (27)$$

From free body diagram Figure 9, Taking moment about c

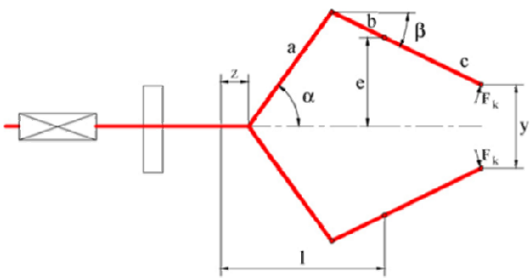


Figure 9: Configuration 3 Free Body Diagram

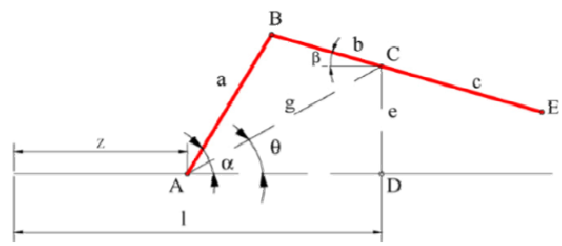


Figure 10: Configuration 3 Free Body Diagram

$$F_k c\cos(\beta) = bR\sin(\alpha) \quad (28)$$

On combing equations,

$$F_k = \frac{Pb\sin(\alpha)}{2c\cos(\alpha)\cos(\beta)} \quad (29)$$

From Fig. 10 we can define link relations as,

From Δ ADC,

$$g^2 = (l - z)^2 + e^2 \quad (30)$$

By law of cosines & From Δ ABC,

$$b^2 = a^2 + g^2 - 2ag\cos(\alpha - \Phi) \quad (31)$$

which implies,

$$\alpha = \cos^{-1}\left(\frac{a^2 + g^2 - b^2}{2ag}\right) + \Phi \quad (32)$$

From Δ ABC

$$a^2 = b^2 + g^2 - 2bg\cos(\beta + \Phi) \quad (33)$$

which implies,

$$\beta = \cos^{-1}\left(\frac{b^2 + g^2 - a^2}{2bg}\right) - \Phi \quad (34)$$

From Δ ADC

$$\Phi = \tan^{-1}\left(\frac{e}{l-z}\right) \tag{35}$$

Likewise, optimization carried out by modifying MATLAB equations for the present configuration and genetic algorithm is carried out. Results obtained are tabulated in table 3.

Table 3: Optimum Values for Configuration 3

Variable	a	b	c	e	l	z	δ	fval
Opt - Values	30.56	142.07	137.87	4.99	204.21	92.78	3.14	0.6919

Configuration 4

Now a three-fingered gripper is considered, considering configuration as shown in figure 11. Link lengths are represented by variables a, c & e. Intermediate length is represented by b, d & f. angle p, q, r represents horizontal angles. And angle s represents input angle. Considering free body diagram Figure 12,

Figure 11: Configuration 4

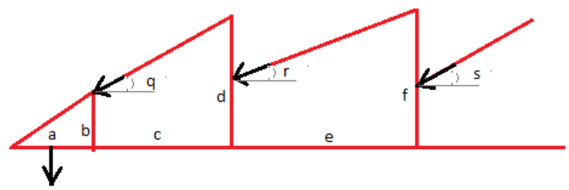


Figure 12: Configuration 4 Free Body Diagram

By following same procedure as per the previous configurations, From Figure 12

$$F_1 = \frac{2\,bF_2\cos(q)}{a} \tag{36}$$

$$p = \sin^{-1}\left(\frac{2b}{a}\right) \tag{37}$$

$$F_3 = \frac{2\,bF_2\cos(r)}{d} \tag{38}$$

$$q = \sin^{-1}\left(\frac{d-b}{c}\right) \tag{39}$$

$$F_4 = \frac{2\,dF_3\cos(s)}{f} \tag{40}$$

$$r = \sin^{-1}\left(\frac{f-d}{e}\right) \tag{41}$$

$$F_4 = \frac{2\,aF_1\cos(p)\cos(q)\,cos(r)\,cos(s)}{f} \tag{42}$$

By altering MATLAB equations to match that of configuration and providing appropriate constrains and limits, we get the optimised result as shown in table 3.

Table 4: Optimum Values for Configuration 4

Variable	a	b	c	d	e	f	*s(rad)*
Opt - Values	22.04	11.02	54.86	65.88	102.57	102.49	1.57

RESULTS AND DISCUSSION

Individual static force calculations for each configuration is made separately and are tabulated in Table 5. Variables represents parameters which define link length and intermediate length as per the configurations, angle is link angle δin case of first three configurations, and input angle s in case of configuration 4.

Table 5: Optimum Values and Function Value

Variable	Config -1	Config -2	Config -3	Config -4
l_1	40.40	22.25	30.56	22.04
l_2	129.60	72.75	142.07	11.02
l_3	196.08	132.23	137.87	54.86
l_4	30.91	0.72	4.99	65.88
l_5	177.26	146.10	204.21	102.57
l_6	99.98	51.10	92.78	102.49
ang (in rad)	3.50	3.14	3.14	1.57
fval	0.022	0.0039	0.6919	0.3833

From table 5, configuration 2 have the minimal function value, which means that from the all configurations and all the possible link lengths available configuration 2 have the minimal function value. Recalling out objective in MATLAB it was about minimizing the function, thus we can say that configuration 2 is the best possible optimal solution. And the optimum link lengths are as mentioned in table.

CONCLUSIONS

As per the discussion carried out, it’s clear that for configuration 2 have the minimum input force required for an output gripping force. So, this configuration can be considered as the optimal model from the considered models. Optimum variables for configuration are given by,

a = 22.25

b = 72.75

c = 132.23

e = 0.72

l = 146.10

z = 51.10

δ = 3.14

By proving slight variations in the MATLAB program, we can extend this method to any available configuration. While comparing with other known methods this method is simpler, efficient and less time consuming.

REFERENCES

1. *R.A. Abu Zitar, (2005),"Optimum gripper using ant colony intelligence", Industrial Robot: An International Journal, Vol. 32 Iss 1 pp. 17 – 23*
2. *I Cheng, C. H. Liu and Yin-Tien Wang., “Contact Force Analysis in Static Two-Fingered Robot Grasping”, Paper No. DETC2013-12160, 2014.*

3. *Ito, S. Mizukoshi, Y. Ishihara and K. Sasaki, M. International Conference on Intelligent Robots and Systems, IEEE/RSJ ,1588 – 1593, 2006.*

4. *Shahram Hadian Jazi, Mehdi Keshmiri and Farid Sheikholeslam. "Dynamic Analysis and Control Synthesis of Grasping and Slippage of an Object Manipulated by a Robot", Advanced Robotics,22:13-14, 15591584, 2008.*

5. *B. Barkat, S. Zeghloul, and J. P. Gazeau, "Optimization of grasping forces in handling of brittle objects"., Robotics and Autonomous Systems, vol. 57, no. 4, pp. 460–468, 2009.*

6. *A.M. Zaki, O.A. Mahgoub, A.M. El-Shafei, and A.M. Soliman., "Design and Implementation of Efficient Intelligent Robotic Gripper", The Open Mechanical Engineering Journal Issue 11, Volume 9, November 2010.*

7. *Garg S, Dutta A. Grasping and manipulation of deformable objects based on internal force requirements. International Journal of Advanced Robotic Systems. 2006;3(2):107-14.*

8. *Rituparna Datta and Kalyanmoy Deb, Optimizing and Deciphering Design Principles of Robot Gripper Configurations Using an Evolutionary Multi-Objective Optimization Method, 2011.*